FISCAL YEAR 2000 RESEARCH PROPOSAL COVER PAGE

STRATEGIC ENVIRONMENTAL RESEARCH AND DEVELOPMENT PROGRAM (SERDP)

<table>
<tr><td colspan="2">**1. SON Number: CSSON-00-3**</td><td colspan="2">**2. SERDP No.**
(Office use only)</td></tr>
<tr><td colspan="4">**3. Proposal Title:**
Disturbance of Soil Organic Matter and Nitrogen Dynamics: Implications for Soil and Water Quality</td></tr>
<tr><td colspan="2">**4. Principal Investigator Name:**
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<tr><td>**6. Type of Organization:**</td><td>**[X] Government**</td><td>**[ ] Educational Institution**</td><td>**[ ] Business**</td></tr>
<tr><td>**6a. Organization Subcategory:**</td><td>**[ ] GOGO**
[ ] GOCO
[X] FFRDC</td><td>**[ ] HBCU**
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<tr><td>**8. Estimated Cost:**
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NOTHING ON THIS PAGE IS PROPRIETARY INFORMATION

2. Abstract

We propose to conduct studies of soil organic matter and soil nitrogen dynamics across a range of spatial scales at Fort Benning, Georgia. The proposed studies will concentrate on the effects of anthropogenic and natural disturbances on key measures of soil quality and the potential recovery of soil quality following disturbance, as indicated by an analysis of soil carbon and nitrogen dynamics. We also plan to use GIS resources from Fort Benning for the purpose of scaling measurements at particular sampling locations to a site-wide spatial analysis of soil quality, soil nitrogen dynamics, and the potential for soil carbon sequestration. The research will be coordinated with field studies developed for existing SERDP projects. The overall objectives of this study are to (1) describe how soil carbon and nitrogen dynamics are affected by current DoD land use activities and natural disturbance regimes, (2) describe how current DoD activities and/or land use activities affect the potential for short- to long-term recovery of soil quality in disturbed environments, (3) use existing GIS resources as a tool for analysis of spatial patterns of soil carbon and nitrogen and (4) predict the effect of site disturbance and/or land use change on soil quality and nonpoint sources of nitrogen to surface water drainages. GIS being developed by existing SERDP projects at Fort Benning will be used to support this effort. Field data and models developed during the course of this project will be made available for incorporation into the Fort Benning GIS that is maintained by the US Army Engineer Research and Development Center on behalf of Fort Benning.

3. Technical Section

a. SERDP Relevance

This proposal is relevant to SERDP because it addresses the following objectives in the Statement of Need Number CSSON-00-03 entitled “Ecological Disturbance In The Context Of Military Landscapes”:

1. to identify the historical range of variation in types, spatial extent, intensities and frequencies of natural disturbances across the landscape associated with specific ecological and/or land use conditions;
2. to describe how current DoD activities within the ecosystem compare to past disturbance regimes, in terms of affecting specific ecological and/or land use conditions; and
3. to determine whether there are thresholds in spatial extent, intensity or frequency above and/or below which the natural system cannot sustain identified ecological and/or land use disturbances.

We propose to conduct studies of soil organic matter and soil nitrogen dynamics across a range of spatial scales at Fort Benning, Georgia, to contribute to the three goals outlined above. The proposed studies will concentrate on the effects of anthropogenic and natural disturbances on soil quality and the potential recovery of soil quality following disturbance, as indicated by an analysis of soil carbon and nitrogen dynamics. We also plan to use available GIS resources from Fort Benning for the purpose of scaling measurements at particular sampling locations to a site-wide spatial analysis of soil quality, soil nitrogen dynamics, and the potential for soil carbon sequestration. The research will be integrated with field studies developed for an existing SERDP project entitled “Indicators of Ecological Change” (Dale et al. 1999) as well as other SERDP research projects at Fort Benning, including: "Determination of Indicators of Ecological Change" (W. F. DeBusk et al.), "Development of Ecological Indicator Guilds for Land Management" (A. J. Krzysik et al.), and "Thresholds of Disturbance: Land Management Effects on Vegetation and Nitrogen Dynamics" (B. S. Collins et al.).

The proposed work will contribute to an analysis of land-based carrying capacity (LBCC) which is the ability of specific land parcels to accommodate military training, testing, and mission activity. The LBCC concept is of significant relevance to SERDP. The Office of the Deputy Chief of Staff for Operations and Plans (ODCSOPS) stated “Installation training managers need to identify carrying capacity of training lands, predict the impacts of land based usage, understand risk associated with use, analyze decisions to provide training flexibility versus environmental or ecological damage”. Furthermore, the need for “efficient tools, models, and techniques to characterize, integrate constraints and quantify the capability of DoD lands and natural resources to support the military training and testing missions and other appropriate uses on a sustained basis” is DoD Conservation requirement priority 4. Our proposed research will help managers predict the impacts of various land uses on key determinants of soil quality at Fort Benning.

b. Technical Objectives

The overall objectives of this study at Fort Benning are to:

1. characterize the effect of disturbances and land use on key measures of soil quality (i.e., describe how soil carbon and nitrogen dynamics are affected by current DoD land use activities and natural disturbance regimes),
2. determine whether there are thresholds associated with natural and/or anthropogenic disturbance that establish the potential recovery of soil quality on disturbed lands (i.e., describe how current DoD activities and/or land use activities affect the potential for short- to long-term recovery of soil quality in disturbed environments),
3. use existing GIS resources as a tool for analysis of spatial patterns of soil carbon and nitrogen and predict the effect of site disturbance and/or land use change on soil quality and nonpoint sources of nitrogen to surface water drainages,
4. build dynamic models of soil organic matter for different land use categories to predict the recovery of soil quality and soil carbon sequestration on degraded soils, and
5. plan long-term field experiments to test landscape based models used to predict the recovery of soil quality (including soil carbon sequestration) following disturbance caused by DoD activities.

c. Technical Approach

1) Background

Soil quality is the "ability of soil to continue to function in its natural condition within the ecosystem" (see e.g. Eijsackers 1998). Vegetation dynamics and the sustainability of terrestrial ecosystems depend on soil quality. Deterioration in soil quality can lead to dramatic and permanent changes in plant communities. However, little is known about what thresholds may exist that prolong or prohibit a recovery of soil quality following anthropogenic or natural disturbances.

Soil organic matter and soil nitrogen dynamics, along with soil texture and soil structure, are critical determinants of soil quality (Torstensson et al. 1998). Soil organic matter affects soil moisture availability as well as nutrient availability to plants. The restoration of vegetation and ecosystems on disturbed lands will be seriously impeded without an adequate supply of soil nutrients. Soil nitrogen availability, in particular, directly affects the net primary productivity of plant communities occupying highly weathered and highly leached Ultisols throughout the southeastern United States.

It is well established that ecosystem disturbance can lead to short-term increases in soil nitrogen availability (Vitousek et al. 1979, Matson and Vitousek 1981) and long-term declines in soil organic matter (Mann 1986, Davidson and Ackerman 1993). Soil disturbance may increase the flux of nitrogen and organic matter from the terrestrial to the aquatic environment. Long-term changes in soil organic matter and soil nitrogen dynamics may also affect the potential recovery of disturbed ecosystems. Changes in land use associated with DoD activities at Fort Benning may have both short- and long-term effects on soil quality. There is a mosaic of activities at Fort Benning, including military activities, ecosystem disturbance, fire, and land use change, that have potential impacts on soil quality and the sustainability of natural ecosystems.

Military activities may result in erosional losses of surface soils and changes in soil structure through compaction by troops and machinery. Soil erosion can seriously deplete past or recent stocks of surface soil organic matter and compaction may disrupt soil aggregate structure exposing intra-aggregate soil organic matter to accelerated decomposition. These effects may lead to a gradual deterioration in soil quality depending on the extent, intensity, and frequency of disturbance. It is unclear whether there are disturbance thresholds that ultimately influence the rate of recovery or final state of soil quality on lands impacted by military activities.

Ecosystem disturbance can produce changes in soil temperature and potentially alter soil nitrogen and carbon dynamics. Forest clearing may increase soil temperature with a subsequent increase in the rate of soil nitrogen transformations (particularly nitrification) (Joslin and Wolfe 1993, Swift et al. 1993). Blackening of the soil surface by fire can lead to increased day-time temperatures which may affect soil microbiological processes leading to higher rates of soil organic matter decomposition. Fires can also result in losses of surface soil organic matter and short-term changes in nutrient availability (Raison 1979). More needs to be known about the use of fire as a management tool and its potential effect on measures of soil quality like nitrogen availability and soil organic matter.

Land use change can impact both the amount of soil organic matter present and its turnover time (Compton et al. 1998, Wang et al. 1999). Increased soil bulk density and lowered soil organic matter appear to be persistent legacies from prolonged soil disturbance through cultivation (Compton et al. 1998). Soil organic matter and soil nitrogen dynamics will vary spatially and temporally at Fort Benning depending on land use and land cover. More needs to be known about variation in soil quality within different land use categories and how this information can be extrapolated to larger scales using GIS to assess site-wide impacts of land use change on soil carbon and nitrogen dynamics. Eventually, soil quality measures could be incorporated into land use planning and land management to sustain natural ecosystems at Fort Benning.

Some researchers have proposed that recovery of soil carbon on degraded or intensively cultivated lands could help to restore soil quality and alleviate increasing atmospheric carbon dioxide concentrations that may lead to global warming (e.g., Lal et al. 1998). For a variety of reasons, land-use change in the United States may be accelerating terrestrial carbon sequestration. Planting of herbaceous bioenergy crops, like switchgrass (Bransby et al. 1998), or other types of land use change, like agroforestry, may increase the potential to sequester carbon in soils, however it is difficult to critically evaluate such proposals because of a lack of data on soil carbon dynamics.

There are two basic approaches that can be used to obtain the data necessary to model recovery of soil organic matter on disturbed lands: chronosequence studies (e.g., Balesdent et al. 1998, Boerner et al. 1998) and stable isotope techniques (e.g., Balesdent et al. 1988). Recently, we have used physical methods of soil fractionation in combination with an analysis of stable carbon isotopes to develop a simple model of soil carbon dynamics beneath herbaceous vegetation and forest ecosystems. The model considers two soil carbon pools: (1) particulate organic matter (POM), and (2) mineral associated soil organic matter. POM consists of "free" soil organic matter and large fragments (≥ 0.053 mm) of organic matter released by dispersion of soil aggregates. Given its fast turnover, soil carbon in POM is important to soil quality over the short-term (1 to 10 years). The mineral associated soil organic matter consists of soil organic carbon associated with silt and clay size particles. Protection of organic matter occurs through soil aggregate formation, interactions of soil organic carbon with silt and clay (i.e., organomineral soil organic matter), and humification (Jastrow 1996). This simple model could be implemented within the framework of a GIS to predict the recovery of soil organic matter, and soil quality, at multiple spatial scales, following soil disturbance at Fort Benning.

In summary, the expected payoffs of the proposed work are an improved understanding of:

1. soil organic matter and soil nitrogen dynamics in different land use categories at Fort Benning and a mapping of the spatial distribution of these aspects of soil quality,
2. the effects of soil disturbance on soil organic matter and soil nitrogen dynamics including the potential for recovery of soil quality following disturbance, and
3. how management decisions on land use change may impact soil quality and the potential for soil carbon sequestration on degraded lands.

2) Methods

The following five tasks correspond to the technical objectives:

Objective 1. Characterize the effect of disturbances and land use on key measures of soil quality (i.e., describe how soil carbon and nitrogen dynamics are affected by current DoD land use activities and natural disturbance regimes).

Task 1 - In the first year, we will measure the range of variation in soil bulk density, soil carbon, and soil nitrogen in ecosystems along gradients of disturbance and land use change (e.g., forests, old-fields, disturbed, and undisturbed lands). A hierarchical classification of broad land use categories, disturbance regimes, soil types, and topography will be developed on the basis of GIS data layers available from Fort Benning. Stratified random soil sampling will be employed within the classification scheme. Soil samples will be collected to a depth of 20 cm along transects in the different sampling strata. The samples will be divided into surface litter and mineral soil and both portions will be analyzed for bulk density, soil texture, and total carbon and nitrogen. Whenever possible, we will include soil sampling at locations where there has been a past shift in plant community type (from C_3 to C_4 vegetation or visa versa). These latter samples will be analyzed for stable carbon isotopes to determine if there are existing isotopic signatures from past land use practices that can be used to determine the dynamics of soil carbon for models of soil organic matter. Inventories of total soil carbon and nitrogen will be calculated and expressed on a g/m^2 basis. Soil nitrogen availability will be determined on a subset of soil samples from each land cover or disturbance class by measuring net nitrogen mineralization potential under laboratory conditions. As part of the laboratory study, we will quantify extractable soil ammonium and nitrate in different terrestrial environments at Fort Benning.

Facilities and equipment in the Environmental Sciences Division at Oak Ridge National Laboratory include a: (1) VG SIRA Series II dual inlet isotope ratio mass spectrometer for analysis of stable carbon isotope ratios, (2) Perkin Elmer 2400 Series II CHNS/O Analyzer for analysis of total carbon and nitrogen in plant and soil samples, and (3) Technicon Traacs 800 Analyzer for the determination of ammonium and nitrate in soil extracts. Two associated laboratories house equipment and areas devoted to the handling and preparation of soil samples for analysis.

Data from the first year's work will be mapped within the framework of a GIS that portrays different categories of land use/land cover (LULC) and disturbance history and which is being developed in conjunction with Dale et al. (1999) The preliminary spatial analysis should reveal patterns in measures of soil quality that can be extrapolated to the entire Fort Benning site. The range of variation in various measures of soil quality will be used to plan sampling activities during the second year and to make any required modifications to the land use/land cover, and soil classification scheme. The soil data will also allow us to calculate the minimum number of samples needed to statistically estimate various measures of soil quality in each sampling category with a specified accuracy (e.g., 5, 10, or 20 % of the mean). The soils data will also allow us to determine if underlying geology or broad soil taxa are important. Most of the data analysis and interpretation will be deferred until the 3rd and 4th years of the project when there is less demand on investigator time by field work.

Objective 2. Determine whether there are thresholds associated with natural and/or anthropogenic disturbance that establish the potential recovery of soil quality on disturbed lands (i.e., describe how current DoD activities and/or land use activities affect the potential for short- to long-term recovery of soil quality in disturbed environments).

Task 2 - In the second year, we will focus studies of soil quality along chronosequences of disturbance at Fort Benning. This approach will allow us to explore disturbance thresholds that impact the potential for short- and long-term recovery of soil quality. The number of samples required for both short- and long-term studies will be estimated on the basis of data from Task 1.

For studies of short-term recovery, we will conduct soil sampling at four or five sites impacted by varying degrees of military activity and burning at Fort Benning. If possible, reference (undisturbed) sites will be established as controls for comparison with disturbed sites. Soil studies will commence immediately following disturbance and follow-up sampling will be conducted on a seasonal basis (winter, spring, summer, and fall). For the long-term studies, we will conduct soil sampling along existing gradients of ecosystem recovery (i.e., a one-time sampling of soils in ecosystems at different stages of recovery following varying degrees of anthropogenic disturbance).

The principal measures impacted by anthropogenic and/or natural disturbance will be soil nitrogen availability and labile soil organic carbon. Changes in soil nitrogen availability, following disturbance, will be measured by *in situ* incubations using closed-top, solid cylinder soil cores (Hart et al. 1994). The cores (20 cm deep) will be incubated 45 days in the field and then recovered to determine net nitrogen mineralization and nitrification potential. The field data will be supplemented with laboratory incubations (as necessary), using published methods (Garten et al. 1994), to assess the impact of disturbance intensity on soil nitrogen dynamics. Changes in labile soil organic carbon will be evaluated by an analysis of particulate organic matter (Cambardella and Elliot 1992). Soil samples taken at the beginning of the *in situ* incubations for nitrogen mineralization will be used to determine the recovery or loss of labile soil organic carbon, relative to control sites, following disturbance. Again, much of the final data analysis and interpretation will be deferred to the 3rd and 4th year of the project when there is less demand on investigator time by field work.

Objective 3. Use existing GIS resources as a tool for analysis of spatial patterns of soil carbon and nitrogen and predict the effect of site disturbance and/or land use change on soil quality and nonpoint sources of nitrogen to surface water drainages.

Task 3 - In the third year, we will use available GIS data layers (e.g., LULC, disturbance history, soils, geology, and topography) at Fort Benning in combination with the field data (collected during Task 1 and 2) to analyze spatial patterns in soil quality and evaluate the role of disturbance as a nonpoint source of nitrogen to surface waters at Fort Benning.

Predicted changes in soil carbon inventories (Task 2) will be mapped as a function of disturbance history, land cover, geology, topography, and soil type. This information, in the framework of a GIS and in combination with data on existing soil carbon stocks under different land use/land cover categories (Task 1), can be used to predict the effect of disturbance on organic matter as a measure of soil quality and the recovery of soil carbon following site disturbance. Associated changes in soil nitrogen availability may constrain the recovery patterns for organic matter on the landscape. Sites with relatively high soil nitrogen availability will have greater ecosystem productivity and a greater potential for inputs to belowground carbon stock. Soil texture may also have a strong influence on the potential recovery of soil quality. Pools of mineral-associated organic matter may recover more quickly on soils with a high silt-clay content because of a greater opportunity for physical protection of soil organic carbon. Multiple hypotheses about spatial patterns in soil carbon and nitrogen as affected by site disturbance, land use change, and soil type can be explored using GIS techniques. Ad hoc soil sampling will be conducted, as required, to fill gaps in information required to execute Task 3.

The importance of soil nitrogen (particularly nitrate) as a nonpoint source to surface receiving waters at Fort Benning will be evaluated using a landscape based nutrient model that is being developed for the Neuse River Basin (Garten and Ashwood 2000). The mass balance model for soil nitrogen will include an assessment of inputs to the available soil nitrogen pool (e.g., atmospheric deposition, net soil nitrogen mineralization) and outputs from the available soil nitrogen pool (e.g., plant uptake, denitrification, and leaching). The nitrogen model will be partially based on site specific data, collected as a part of Task 1 and Task 2, coupled with GIS information on land use/land cover and a disturbance history to map those areas at Fort Benning with the greatest potential for contributing nitrogen to surface waters. This information could help to implement best land management practices that will allow Fort Benning to meet forthcoming EPA requirements of total maximum daily loads to surface waters.

Objective 4. Build simple dynamic models of soil organic matter and soil nitrogen for different land use categories to predict the recovery of soil quality and soil carbon sequestration on degraded soils.

Task 4. In the last year, we will focus on studies directed at modeling soil carbon dynamics under different land use categories (e.g., forests, oldfields, lawns). Soil sampling during the first year (Task 1) will allow us to identify sites where measurements of stable carbon isotope ratios can be used to derive estimates of soil carbon inputs and the turnover time of different soil carbon pools. Growing a C_4-plant (like bermudagrass or corn) on soils previously occupied by C_3-plants (e.g., forest vegetation) gives rise to a soil organic matter labelling experiment because C_3 and C_4-plants have different stable carbon isotope ratios (Smith and Epstein 1971). As described elsewhere (Balesdent et al. 1987, Balesdent et al. 1988), the fraction of newly derived soil organic carbon in whole soil or a soil part (e.g., particulate organic matter) can be calculated from data on stable carbon isotope ratios following a switch from C_3 to C_4 vegetation (or visa versa). The turnover times of various fractions of soil organic matter can be calculated from a comparison of stable carbon isotope ratios in labelled soils with reference soils. Specifics about the experimental design, i.e. number of study sites and number of samples, will have to be determined upon completion of Task 1. Given that agriculture was historically important on lands now occupied by Fort Benning, we believe there is a good chance of finding stable carbon isotope signals that can be used to parameterize simple models of soil organic carbon dynamics developed at ORNL (Garten et al. 1999). These models will be used to predict the potential for recovery of soil organic matter following disturbance and the potential to sequester soil carbon on degraded soils.

Objective 5. Plan long-term field experiments to test landscape based models used to predict the recovery of soil quality (including soil carbon sequestration) following disturbance caused by DoD activities.

Task 5 - Tasks 1 and 2 will provide the data needed for assessment and model development. Tasks 3 and 4 will provide the spatial and dynamic models required to predict soil organic matter and nitrogen dynamics in different land use categories and the potential for recovery of soil quality following disturbance. In the final year, Task 5 will include the planning and design of long-term field experiments to test model predictions by disturbing natural soils or setting aside disturbed sites to monitor the recovery of soil organic matter and nitrogen dynamics under different vegetative covers (including tree plantations and bioenergy crops). This task will be coordinated with a similar task described in the SERDP Project entitled "Indicators of Ecological Change" (Dale et al. 1999) and any other planned long-term studies by other SERDP research teams.

3) Milestones

FY 2000 Task 1: (a) Develop hierarchical soil sampling plan based on GIS data layers; (b) Complete preliminary surveys of soil carbon and nitrogen under different categories of LULC, soil type, and topography (c) complete preliminary analysis of soil carbon and nitrogen stocks under different LULC categories; (d) Interim Progress Report and Meeting; Annual report.

FY 2001 Task 2: (a) Establish study sites along a disturbance gradient with controls; (b) Complete preliminary analysis of *in situ* net nitrogen mineralization along a disturbance gradient; (c) Complete preliminary analysis of particulate organic matter along a disturbance gradient; (d) Progress Report and Meeting; Annual report.

FY 2002 Task 3: (a) Complete mapping of soil organic matter and soil nitrogen under different LULC categories; (b) Evaluate and interpret importance of different LULC categories as nonpoint contributing sources to nitrogen in surface receiving waters at Fort Benning; (c) Complete *ad hoc* sampling to fill missing data for GIS analysis; (d) Interim Progress Report and Meeting; Annual report.

FY 2003 Task 4 and 5: (a) Parameterize simple models of soil organic matter for different LULC and soil type categories; (b) Complete design planning of long-term field experiments to test model predictions of soil carbon and nitrogen dynamics; (c) Final report and Project Plan for Long-term Field Experiments.

d. Research Team

Charles T. Garten, Jr., Senior Research Staff Member, Environmental Sciences Division, 25 years experience in basic and applied environmental studies; including field and laboratory research related to terrestrial ecology, environmental chemistry, radioecology, environmental behavior of hazardous chemicals, biogeochemical dynamics in ecosystems, and ecosystem modeling. **Tom Ashwood,** Program Manager, Environmental Sciences Division, ecological modeling to support adaptive land management.

e. Cooperative Development

This project will interface with an existing SERDP Project at ORNL entitled "Indicators of Ecological Change" (Dale et al. 1999) as well as four other funded research projects at Fort Benning. Part of the previously funded work includes tasks directed at evaluating aquatic indicators of landscape disturbance, including "within-stream" indicators (e.g., stream water chemistry and metabolism). Our proposed work would help provide a linkage between soil organic matter dynamics and soil nitrogen availability at the landscape scale and water chemistry in study catchments at Fort Benning. The "Indicators" project also includes plans for field experiments to test the effects of terrestrial impacts and the success of restoration activities (see Task 5). Our proposed work on soil organic matter and nitrogen dynamics would include experiments on soil quality in the context of the larger "Indicator" experiments. Overall, the characterization and modeling of soil organic matter and nitrogen dynamics in different ecosystems at Fort Benning would add value to several previously funded research efforts at Fort Benning, including: "Determination of Indicators of Ecological Change" (W. F. DeBusk et al.), "Development of Ecological Indicator Guilds for Land Management" (A. J. Krzysik et al.), and "Thresholds of Disturbance: Land Management Effects on Vegetation and Nitrogen Dynamics" (B. S. Collins et al.).

This project will also interface with DOE funded research projects at ORNL on: 1) soil carbon dynamics in forest ecosystems (see e.g., Garten et al. 1999), 2) soil carbon and nitrogen dynamics under the bioenergy crop switchgrass (see e.g., Garten and Wullschleger 1999), and 3) research on spatial patterns of soil carbon sequestration on the Oak Ridge Reservation (Garten and Ashwood 2000) funded in association with DOE's Center for Research on Enhancing Carbon Sequestration in Terrestrial Ecosystems (CSITE). Data from these DOE projects in combination with data from the proposed work will help contribute to regionally explicit models of soil carbon dynamics in the southeastern United States. Information from the switchgrass research being conducted at ORNL (Garten and Wullschleger 2000) could also be of direct benefit in restoration of disturbed lands at Fort Benning. Also, an EPA funded project on development of spatially explicit GIS models for predicting nonpoint nitrogen sources in the Neuse River Basin (Garten and Ashwood 2000) could provide a framework for similar assessments of nonpoint nitrogen sources to surface drainage waters from Fort Benning.

f. Transition Plan

GIS being developed by existing SERDP projects at Fort Benning will be used to support this effort. Field data and models developed during the course of this project will be made available for incorporation into the Fort Benning GIS that is maintained by the US Army Engineer

Research and Development Center (ERDC 1999) on behalf of Fort Benning. Data and models will be published in peer-reviewed scientific journals and will be presented at scientific and military meetings, including the annual SERDP/ESTCP Symposium. The project data and results will also be incorporated into ORNL's SERDP website.

4. Cost Estimate

			Year 1		Year 2		Year 3		Year 4	
	Item	Description	FTE	Total	FTE	Total	FTE	Total	FTE	Total
a.	Labor Costs	C. T. Garten	0.30	$78,000	0.50	$134,500	0.30	$81,000	0.30	$83,000
		T. L. Ashwood	0.25	$60,000	0.34	$83,000	0.22	$55,000	0.21	$52,500
		B. Lu	0.20	$35,000	0.25	$45,000	0.20	$36,500	0.20	$37,000
		Student	0.33	$6,000	0.33	$6,000	0.33	$6,000	0.33	$6,000
b.	Major Equipment	None		$0		$0		$0		$0
c.	Materials & Supplies	Lab Supplies		$2,000		$3,000		$1,000		$1,000
		Computer Facility	0.15	$4,000	0.15	$4,000	0.15	$4,500	0.15	$4,500
d.	Gov't. Partners and Subcontracts	None		$0		$0		$0		$0
e.	Travel Costs	SAB Meeting	2	$2,000						
		SERDP IPR	2	$2,500	2	$2,500	2	$2,500	2	$2,500
		SERDP Symposium	2	$3,000	2	$3,000	2	$3,000	2	$3,000
		Benning Scoping Trip	2	$1,500	2	$1,500				
		Benning Field Work	2	$3,000	2	$5,000	2	$3,000	2	$3,000
		Benning Coordination Trips	8	$2,000	6	$1,500	6	$1,500	6	$1,500
f.	Publications			$1,000		$1,000		$1,000		$1,000
g.	Consultants	None		$0		$0		$0		$0
h.	Cost Summary	ORNL		$200,000		$290,000		$195,000		$195,000

5. **Appendices**

a. **Abbreviated Curriculum Vitae**

Charles T.Garten, Jr.

CURRENT POSITION

Senior Research Staff Member
Ecological Sciences and Earth Sciences Section
Environmental Sciences Division, Building 1505
Oak Ridge National Laboratory, P. O. Box 2008
Oak Ridge, Tennessee 37831-6038
Phone: (423) 574-7355
E-mail: ctg@ornl.gov

EXPERIENCE SUMMARY

25 years experience in basic and applied environmental studies; including field and laboratory research related to terrestrial ecology, environmental chemistry, radioecology, environmental behavior of hazardous chemicals, biogeochemical dynamics in ecosystems, and ecosystem modeling

EMPLOYMENT HISTORY

Research Staff Member, Environmental Sciences Division, Oak Ridge National Laboratory (Lockheed Martin Energy Research Corporation), Oak Ridge, TN (1983-1997)

Research Associate, Environmental Sciences Division, Oak Ridge National Laboratory (Union Carbide Corporation), Oak Ridge, TN (1976-1983)

Research Technical Coordinator, Savannah River Ecology Laboratory (University of Georgia), Aiken, SC (1973-1976)

EDUCATION

East Tennessee State University, Graduate studies in Environmental Health, 1995-present

University of Georgia, M. S. (Zoology), 1974

University of Alberta, Canada, Graduate studies, 1971

Washington and Lee University, B. S. (Biology), 1970

CURRENT RESEARCH INTERESTS

Forest soil carbon and nitrogen dynamics as part of the global carbon cycle; applications of stable isotopes to studies of forest nutrient dynamics; identification of anthropogenic sources of atmospheric nitrogen deposition; atmosphere-canopy interactions of sulfur and nitrogen in forests; applications of reduced computer models to predict the fate of elements, hazardous materials, and the behavior of long-lived radionuclides in terrestrial ecosystems

AWARDS AND HONORS

Scientific Achievement Award, Environmental Sciences Division, Oak Ridge National Laboratory (1989); Martin Marietta Energy Systems Technical Achievement Award (1989)

PROFESSIONAL ACTIVITIES

Section Editor, Nuclear Safety (1978-82)

American Chemical Society, Member

Sigma Xi (The Scientific Research Society), Member

Associate Editor, Journal of Environmental Radioactivity (1993-1996)

National Council on Radiation Protection and Measurements Scientific Committee No. 64 - "Radiocesium in the Environment" (1997-99)

SELECTED PUBLICATIONS (95 total)

Garten, C. T., Jr., L. W. Cooper, W. M. Post, III, and P. J. Hanson. 1999. Climate controls on soil C isotope ratios in forests along an elevation gradient in the southern Appalachian Mountains. Ecology (in press).

Hanson, P. J., N. T. Edwards, C. T. Garten, Jr., and J. A. Andrews. 1999. Separating root and soil microbial contributions to soil respiration: a review of methods and observations. Biogeochemistry (in press).

Garten, C. T., Jr., and S. D. Wullschleger. 1999. Soil carbon inventories under a bioenergy crop (switchgrass): measurement limitations. Journal of Environmental Quality 28: 1359-1365.

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EDUCATION

BS, Mechanical Engineering, 1969, University of Missouri-Rolla, Rolla, Missouri.

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